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February 14, 2011

Via Electronic and U.S. Mail

Mr. Nigel Robinson
USEPA - Region II
290 Broadway – 19th Floor
New York, New York 10007-1866

Re: ***Chemsol Superfund Site***
Long-Term Monitoring Plan

Dear Mr. Robinson:

As an attachment to an email dated December 1, 2010, the United States Environmental Protection Agency (USEPA) provided comments on the draft March 2010 Long-Term Monitoring Plan (LTMP) and Quality Assurance Project Plan (QAPP) for OU-2, Remedial Work Element (RWE) II, at the Chemsol Superfund site. In preparation for a conference call with USEPA on December 14, 2010, the Chemsol Site Trust (the Trust) provided a draft response to comments for discussion purposes. Agreements on several of the comments were reached during the December 14 conference call and USEPA provided additional feedback via email on December 17, 2010. In addition, the Trust provided additionally requested information, specifically related to the topic of low flow sampling, via email dated December 28, 2010. The USEPA responded via telephone to William Lee on January 6, 2011 with conditional approval to implement the LTMP using low flow sampling methodology. With this approval, final agreement was reached on the contents of the LTMP/QAPP and the baseline groundwater sampling event was started January 10, 2011. Following completion of the baseline sampling event, and subsequent final inspection of the on-site groundwater treatment facility on January 25, 2010, the site-wide groundwater extraction and treatment system (four extraction wells along the northern, down-gradient property boundary and two wells within the central portion of the property) began long-term operation.

As noted above, agreement on these comments resulted in final approval of the LTMP/QAPP and the draft document is currently being revised to reflect the agreed upon changes. The agreed upon changes include those agreed upon with the New Jersey Department of Environmental Protection (NJDEP) in a Technical Memorandum dated August 27, 2010. Final copies of the LTMP/QAPP will be forwarded under separate cover. In the interim, this letter documents each of the Agencies December 1 comments (shown in Italics) followed by a brief response and the agreement reached with USEPA. Additional technical background and discussion associated with several of the comments, and previously forwarded in the submittals referenced above, is attached for reference.

1) Sect. 2.1 - a) A baseline water level round must be collected before turning on the extraction wells. b) Water level data must also be plotted on some north-south cross-sections. c) Changes in the frequency of water level measurements must be approved by EPA. Monthly data collection could be required past the first year, or continued for some selected wells.

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Response:

1A: Agreed. A baseline water level round will be collected before turning on the extraction wells. The on-going interim extraction system (pumping from wells C-1 and C-1P) will continue to operate.

1B: Agreed. A north-south oriented cross section will be drawn through the central portion of the site, through extraction wells C-1 and C-1P. Note that the direction of groundwater flow from off-site to the north across the property's southern border will also be confirmed through the use of data loggers (See Comment 7).

1C) Monthly water level data collected since 1994, as part of the interim groundwater extraction system, consistently indicate that while the overall potentiometric surface fluctuates seasonally, the zone of capture developed by the extraction well remains consistent. The LTMP currently calls for monthly water level measurements during the first year of operation to document that pumping from the new extraction wells will exhibit the same consistency. It was agreed that water levels would be monitored monthly as called for in the LTMP, with the caveat that if the zone of capture fluctuates seasonally, as demonstrated by the monthly data collected during the first year of operation, then monthly water level monitoring would continue beyond the first year of operation in all or a selected sub-set of wells as determined through consultation with USEPA. The LTMP will be edited to reflect this agreement.

2) OW-series wells must be included in the water-level measurement rounds.

Response:

Water levels in OW series wells (overburden wells) are currently collected monthly as part of the interim groundwater extraction system monitoring program in place since 1994. These data, as well as that collected during the Pre-Design Investigation (PDI) consistently indicate that the overburden water surface (water table) is essentially perched on top of the low permeability upper bedrock, it is a vertical flow system (i.e., limited, if any horizontal flow component), and is not responsive to pumping in the underlying bedrock. Based upon over 16 years of monthly data, the collection of water levels from the overburden wells has never provided any valuable information relative to the performance of the interim groundwater extraction system (See Quarterly Monitoring Reports).

It was agreed with USEPA that water levels in "OW" wells located near the pumping wells along the northern property boundary would be obtained monthly during the first year of operation. Assuming the data continue to demonstrate there is no influence from the pumping wells, than the collection of water levels from the "OW" wells would be discontinued after the first year of operation.

3) Sect. 2.2 - Combined influent should be sampled as frequently as needed during startup, *then monthly through the first year and quarterly thereafter.*

Response:

Agreed. The LTMP will be revised accordingly.

4) Sect. 2.2, pg. 2-3 - The text proposes a direct changeover from 3-volume purge to low-flow protocols. The text cites long open rock intervals and large volumes of purge water requiring treatment. The SOP for low-flow sampling requires that the pump intake be placed at a targeted depth to yield a representative sample of aquifer water. However, many of these bedrock wells are several hundred feet deep and they vary in diameter. Work at some other sites suggests that the most transmissive fracture will yield the water to the sampler even if the intake is not right next to that fracture. Please indicate how the PRP Group will evaluate the pump intakes for all the wells. Because of the very limited sampling that has been done at this site, it would be beneficial to test and compare samples from the alternative methods, especially at problematic wells.

Response:

This comment is consistent with Comment #4 provided on June 14, 2010 by the NJDEP. For completeness and technical background, our August 27, 2010 response to NJDEP's comment is summarized in Attachment A. However, based upon NJDEP's October 26, 2010 response which agreed that a study such as that suggested by the EPA in this comment is not necessary, the depth of the pump intake would be determined as follows:

- For new wells with ten foot screened/open rock intervals the pump will be set at the mid-point of the screened/open rock interval

- For existing TW, DMW or C series wells located adjacent to a newer well for which borehole data is available, information from the adjacent borehole will be used to select the depth at which the pump would be set for sampling (i.e., target zones of highest hydraulic conductivity, open fractures based on caliper logging, etc.).

- For existing TW series wells for which borehole data is not available, the pump will be set five feet above the bottom of the borehole.

- For the remaining locations with open intervals greater than ten feet, the pump will be set within the lower half of the screened interval.

The LTMP will be updated to include the above information and to call for the use of three volume purge sampling, or assessment of alternative methods, at a point in the future when VOC concentrations are approaching the water quality standard and decisions are being made relative to the possibility of shutting down one or more extraction wells (see discussion in

Attachment A).

In our teleconference of December 14, 2010, the Agency had suggested purging a minimum of the screen/open interval volume followed by stabilization of the field parameters prior to sampling. In an email dated December 28, 2010, the Trust forwarded a written response to this approach as well as a table of estimated volumes within the long open intervals of concern. As described in greater detail in Attachment A, the Trust does not have any information to either support or refute the proposed approach. However, based upon the research on low flow sampling, the Trust recommended employing the low flow sampling method at all locations for the baseline sampling round, with the pump set at the depths determined as described above and referenced in the table included in Attachment A. In the event that unexpectedly large differences are observed in the results as compared to historical data, then alternative sampling methods would be considered in consultation with USEPA.

The approach described above was verbally approved on January 6, 2011 and the baseline sampling was completed using the low flow sampling methodology. The LTMP will be revised to reflect the above agreement. Please see Attachment A for additional technical background.

5) Sect. 2.2 - The text suggests that VOCs only will be analyzed for performance. However, additional parameters; SVOCs, Pesticides, PCBs, Inorganics, and MNA parameters (which provide information on the aquifer geochemistry) must also be analyzed during the baseline round. Based on these results and previous identification of site COCs, additional analyses of selected constituents could be required regularly.

Response

This comment is consistent with Comment #5 provided on June 14, 2010 by the NJDEP, and based upon the NJDEP letter dated October 26, 2010, they are in agreement with the approach proposed in the LTMP (i.e., VOCs only). Our August 27, 2010 response to the NJDEP comment is paraphrased and further expanded upon in Attachment B.

As discussed with USEPA and detailed in Attachment B, the collection of analytical data other than VOCs will not have any relevance to the protectiveness or meeting the objectives of the groundwater extraction system as called for in the ROD. In an email dated December 17, 2010, the Agency agreed with this approach with the addition that the full suite of data be analyzed at OW-1, TW-4 and TW-5 during the baseline sampling round. The LTMP will be edited to reflect this agreement and that the need for future analysis of the full suite of parameters at these locations would be dependent upon the results. Please see Attachment B for additional detail.

6) Table 1 – The following wells must also be included in the groundwater sampling network:

MW-205P
DMW-7
DMW-10
TW-9
TW-12
TW-13
TW-14
MW-101
MW-104
OW-series wells; especially
OW-1
OW-2
OW-3
OW-4
OW-10
OW-11
OW-12
OW-14 (as suggested by NJDEP)
Based on the results, some of the wells may be eliminated after the baseline sampling and others after the first year of sampling.

Response:

In the August 2007 PDI Report, it was originally proposed that the LTMP include 29 wells located around the perimeter of the site. In response to comments from USEPA, this list was expanded to the current 49 wells based upon the desire to track concentration trends in multiple interior wells. While the potential value of adding wells MW-205P and DMW-10 (both of which are along the northern property boundary) is recognized, the remaining locations have historically demonstrated non-detectable to low level constituent concentrations or are interior to the site. As noted previously, we are no longer in the site characterization phase and the list of wells in the LTMP includes wells around the perimeter of the site as well as a representative number of interior wells to track water quality trends. It is unclear as to what value is added by collecting additional data from interior wells and/or wells that have historically reported non-detectable concentrations. Likewise, it is also unclear as to the value of collecting water quality data from the overburden OW series wells as they represent a vertical flow system (see response to comment 2 above), are not influenced by the groundwater extraction system and are either along the upgradient perimeter or within the central portions of the site. The collection of water quality data from these wells, therefore, does not provide any information relative to meeting the objectives of the ROD. Sampling of these wells will be appropriate at some time in the future relative to future site decisions, but not as part of the long term monitoring plan.

In response to this comment it was initially agreed that MW-205P and DMW-10 would be added to the long term monitoring program. Subsequent to the Agencies December 17, 2010 email, it was further agreed that wells OW-1, OW-2, OW-10 and OW-12 would be sampled during the baseline round for TCL VOCs. The LTMP and associated tables will be revised to reflect this agreement.

7) Sect. 3 - In addition to the cross-section along the north boundary, data must also be plotted on some north-south cross-sections. Data from the water level recorders should be illustrated in hydrographs too. As the PRP Group indicated, the type of data analysis and frequency could be changed if required by EPA.

Response:

Agreed. A north-south oriented cross section and hydrographs of the water level data recorders will be provided and the LTMP will be edited to reflect this requirement.

8) Sect. 3. - Attached is a template for reporting data O&M at pump and treat sites that was published a few years ago. Please use template as a guide for report preparation. In addition, data should be presented in electronic spreadsheet Region 2 EDD format. Well location (geographic) and construction data should also be provided in EDD format.

Response:

Agreed. The referenced reporting format will be used as a template and the data will also be provided in the Region 2 EDD format. The LTMP will be edited to reflect this agreement.

9) QAPP Worksheet #18 - a) See comment #6 above. b) Provide some additional well construction information, including diameter and inner casing/screen material. A well assessment inventory will be requested at a later time.

Response:

9A: Please see response to comment 6 above. Wells MW-205P and DMW-10 have been added to the long term monitoring program and samples will be collected from wells OW-1, OW-2, OW-10 and OW-12 during the baseline sampling round for analysis of TCL VOCs.

9B: Agreed. The tables in the LTMP will be revised to include the requested information.

10) As mentioned during the Five-Year Review site field visit, conducting aquifer pump testing near wells with FLUTe liners has been found to cause failure in a few cases. The PRP Group should contact the FLUTe company and provide EPA with a plan for managing the FLUTe wells that exist and are proposed at the Chemsol site.

Response:

Discussion with Carl Keller of FLUTe indicates that the referenced failure was a rare occurrence where pumping in a nearby well resulted in drawdown of 90 feet below the water table and a resulting head of approximately 100 feet on the FLUTe liner. As a result of this high differential head, a liner failed at a fracture that apparently connected the pumping well and the FLUTe well. There have apparently been three such instances over 14 years and each of them was related to a large head differential. At locations where this is a potential concern, FLUTe has established a procedure to fill the liner with cement-bentonite grout.

At Chemsol we are working with a confined aquifer and the pumping of nearby wells will result in drawdowns of well under ten feet. These limited head differentials will not pose a threat to the liner and filling the liner with cement-bentonite grout is not proposed. Alternatively, we propose to monitor the water level on the interior of FLUTe -203 during the monthly water level events to confirm its integrity and then recommend abandoning this location in late winter 2011 when drilling equipment is coming off the OU-3 work.

We can also monitor the water level inside the liners for the OU-3 wells with FLUTe liners; however, as noted above, the pumping will result in less than 10 feet of drawdown and these wells are even further away than FLUTe 203, so there is no basis for concern.

11) Table-1 – Semi-annual sampling of the extraction wells and combined influence sampling must be conducted for the first four years of operation instead of first three years.

Response:

Agreed. The LTMP will be amended accordingly.

12) Extraction well EX-4P is missing from Figure 1-2, please include.

Response:

Agreed. Figure 1-2 will be updated.

13) QAPP Worksheet # 33 – All reports presenting the results of the sampling and analysis activities performed at this site should be included.

Response:

Agreed.

14) QAPP Worksheet # 36 – The correct Region 2 data validation SOP should be HW-24, Validating Volatile Organic Compounds by SW 846 Method 8260B.

Response:

Agreed. The reference will be corrected.

Please do not hesitate to contact us with any questions you may have. The LTMP is being revised to reflect the stated agreements and a final document will be submitted in February 2011.

Very truly yours,

de maximis, inc.

William J. Lee

Attachments

cc: Martha Goodwin, NJDEP
Alison Saling, Esq., KL Gates
Tim Roeper, Cornerstone Environmental Group, LLC

Attachment A
Technical Background and Discussion In Response to Comment # 4
Use of Low Flow Sampling Protocols

The technical basis behind the recommended low flow sampling methodology was provided in our August 27, 2010 response to the NJDEP's comments and NJDEPs subsequent October 26, 2010 response. The response is paraphrased below and amended to include a response to the Agencies December 14, 2010 suggestion to purge a minimum of the screen/open interval volume followed by stabilization of the field parameters prior to sampling.

The technical basis behind the LTMP is to establish a consistent procedure (i.e., low-flow sampling) at the onset of the baseline sampling event and then moving forward, such that the objectives of the sampling plan (i.e., observing changes over time) are achieved.

It is important to recognize that the wells installed along the northern property boundary during the Pre-Design Investigation, and subsequently used to characterize the plume at the property boundaries, were all constructed with 10' long screened intervals that were selected on the basis of continuous borehole packer test data and geophysics (please see discussion in Section 3.3 of the PDI Report). These wells were specifically screened across open fractures that exhibited higher permeability as compared to the intervals above and below. The water-bearing fractures contributing to the well screen interval have thus been identified and a consistent method of sampling will result in reproducible results. Originally, it had been proposed that only these perimeter wells be sampled as part of the LTMP since it was recognized, based on the data from interim well C-1 and research over the past several years on the behavior of VOCs in the rock matrix, that pumping would be required for decades with only small changes in groundwater quality within the source area. However, the USEPA requested that the LTMP be expanded to include the collection of data from interior wells so that long term trends could be evaluated.

It is these older, interior wells that have longer open intervals. However, potential water quality differences that may be present based upon the position of the pump will have no impact on the decision making regarding performance of the containment remedy. Rather, the data quality objective here is to collect groundwater samples in a consistent manner that will allow for an assessment of long term water quality trends. The proposed sampling plan meets this objective within both the interior and perimeter portions of the plume and the wells monitoring the plume perimeter were installed to monitor a specific targeted interval based upon the borehole testing.

At this point in the site history, we are no longer in the site characterization phase where the actual concentrations are the principal objective, but rather, in the monitoring phase where the principal objective is to record changes with time. Moreover, given that the groundwater extraction and treatment system is being implemented to address total VOC concentrations in fractured rock in excess of 10,000 ppb (along the northern property boundary, higher in the source area) it is unrealistic to expect that VOC concentrations will approach water quality standards anytime in the foreseeable future. For example, the interim pumping remedy at C-1 has been in operation since September 1994 and total VOC concentrations in the Principal Aquifer adjacent to C-1 remain in excess of 1,000 ppb under pumping conditions and concentrations rebound higher when the pump is temporarily shut down for maintenance. Concentrations in the overlying Upper Permeable aquifer remain consistently above 10,000 ppb and concentrations in the Upper Bedrock Aquitard are in excess of 100,000 ppb. Therefore, potential differences in measured concentrations depending on the collection depth of the low flow sample, would not differ around (i.e., above or below) the water quality standard, but rather at higher concentrations above the standard. Such differences would have no impact on decision making relative to the groundwater extraction and treatment system.

Given the above, and that the low flow sampling approach will also provide the most comparable sampling method to the FLUTe wells to be installed and sampled as part of the OU-3, off-site investigation, we recommended low-flow sampling. However, for those older wells constructed with long open intervals, we would also recommend editing the LTMP to indicate the need to collect samples following three purge volumes (historical method) or to assess alternative sampling methods, at a point in the future when total VOC concentrations have declined to levels (i.e., below water quality standards) where decisions will be made relative to potentially turning off one or more of the extraction wells. In this manner, potential differences in water quality associated with the depth of sampling during the routine monitoring program would be addressed when the results will have an impact on decision making. Note that total VOC concentrations are referenced, as VOCs are present at the highest concentrations above water quality standards and will likely be the most recalcitrant in the fractured bedrock, thereby driving the duration of the remedial efforts. However, any decisions relative to potentially turning off one or more of the extraction wells would be based on a full suite of analytical data (i.e., VOCs, SVOCs, pesticides and metals).

In an October 26, 2010 response to the above discussion, NJDEP agreed with the proposed amendments to the LTMP noted above, with additional statements recommending that for any existing TW, DMW or C series wells located adjacent to a newer well for which borehole data was available, that this information be used to select the depth at which the pump would be set for sampling. We are in agreement with this recommendation. NJDEP further recommended that absent such data, the pump be set approximately 5 feet above the bottom of the well at the TW series wells and in the lower half of the well at the remaining locations. We are also in agreement with this recommendation and have incorporated these comments into the proposed amendments to the LTMP as identified in the bulleted items above.

In our teleconference of December 14, 2010, the Agency had suggested purging a minimum of the screen/open interval volume followed by stabilization of the field parameters prior to sampling. In an email dated December 28, 2010, the Trust forwarded a written response to this approach as well as a table of estimated volumes within the long open intervals of concern. As presented in the December 28, 2010 email, it is our understanding that the Agency is concerned that the long open intervals may result in a stabilization of field parameters that are not representative of the water quality and that the objective of the Agencies proposed approach is to first remove potentially stagnant water within the well.

Briefly, there are 26 locations that fall into this category. Most of these wells have an open interval of approximately 25', with one as long as 52 feet. The volume of water within the screened/open rock interval associated with these wells averages approximately 39 gallons per well and ranges from approximately 14 to 76 gallons. The collective total estimated volume within these screened/open rock intervals is 1021 gallons.

We do not have any information to either support or refute the proposed approach. However, while these volumes are not prohibitive, they would require a vehicle to collect the purge water and transport it back to the treatment plant. This would prove problematic at the interior locations within the reconstructed wetlands. More importantly, based upon the information described below and in the low flow sampling research cited in the attached presentation, we believe that representative samples will be obtained using the low flow sampling methodology.

The attached presentation from QED presents research indicating the low flow sampling is applicable in wells with 20 foot screen/open intervals and that the water quality results are controlled by the geology of the surrounding formation and not the pump position. While there is currently no research on screen/open intervals longer than 20 feet, it is anticipated that the same conditions would prevail. Further, small downward gradients are present throughout the site and intra borehole flow would be anticipated from permeable fractures near the top of the borehole to permeable fractures near the bottom of the borehole. Under these conditions, the borehole water would not be stagnant, but rather, would be representative of the intra borehole flow regime.

The concern expressed by USEPA is that the low flow sampling results will not be comparable to the historical results obtained by purging three well volumes of water prior to sampling. While we agree that the results may be different, we do not anticipate large scale changes in the observed concentrations that would alter the conceptual site model or selected remedial action in any way. Perhaps more significantly, it is no longer clear that the results obtained from sampling following three purge volumes should be the basis for comparison. Over the years, three volume purging has fallen out of favor with the preferred alternative being low flow sampling. While it is recognized that this preference is based on the assumption of shorter screen/open intervals (i.e., on the order of 10 – 20 feet), we believe the data collected following three volume purging should be evaluated with the limitations of the sampling method in mind and that the representativeness of future data collected via low flow sampling should be considered. Likewise, and as discussed previously, we believe the data quality objectives for the LTMP are fully met by establishing consistent sampling protocols from this point forward.

Given the above, we recommend employing the low flow sampling method at all locations for the baseline sampling round, with the pump set at the depths referenced in the attached table. In the event that unexpectedly large differences are observed in the results as compared to historical data, then alternative sampling methods would be considered in consultation with USEPA.

The approach described above was verbally approved on January 6, 2011 and the baseline sampling was completed using the low flow sampling methodology. The LTMP will be revised to reflect the above agreement.

Attachment B
Technical Background and Discussion in Response to Comment # 5
Analysis of TCL VOCs as Opposed to Full TCL/TAL Parameter List

The data collected as part of the original RI and the subsequent PDI investigation, during which the full suite (Full TCL/TAL List) of analytical parameters was analyzed; consistently indicate that VOCs represent the analytical fraction with the greatest number of detected compounds and the highest concentrations. In many cases, the reported concentrations are several orders of magnitude above the applicable water quality standard. In comparison, only four SVOC compounds were sporadically detected, with the highest and most frequently reported SVOC above water quality standards being1,2-dichlorobenzene at 5 of the 62 sampled locations. Note that 1,2-dichlorobenzene, as well as 1,3-dichlorobenzene, 1,4-dichlorobenzene and 1,2,4-trichlorobenzene are now analyzed as part of the VOC fraction. The only other SVOC compounds reported above water quality standards included bis(2-chloroethyl) ether ranging from 7.4 to 42 ug/l at five locations and hexachlorobutadiene at 20 ug/l at one location. Similarly, pesticides were reported above water quality standards in only 5 of the 62 sampled locations and the concentrations were low in comparison to the VOCs. For example, the highest reported pesticide concentration was 0.71 ug/l beta-BHC at TW-4. PCB's were not detected above water quality standards in any of the wells. Finally, the most frequently reported inorganics above water quality standards included aluminum, iron, manganese and at a slightly less frequency, arsenic. All four of these constituents are naturally occurring and aluminum, iron and manganese are also reported above water quality standards in both up-gradient and side-gradient wells; suggesting that the concentrations are naturally occurring. Nonetheless, it is evident that the former site activities represent a contributing factor and concentrations above water quality standards are present at the down-gradient property boundary.

Collectively, the data indicate that at any of the locations at which an SVOC, pesticide or inorganic constituent exceeded the applicable water quality standard, VOC constituents also exceeded applicable water quality standards at a greater frequency and at higher concentrations. Therefore, the VOCs serve as an indicator of the overall water quality. Moreover, the high concentrations of the VOCs, coupled with the knowledge that VOCs will diffuse into the rock matrix and therefore serve as a long term source of dissolved concentrations above the water quality criteria, indicate that the VOCs will be the driver relative to the long term operation of the groundwater extraction system. In other words, the knowledge base indicates that the concentrations of the other analytical fractions will likely decline below water quality standards before the VOCs and that the remaining VOC concentrations will dictate the need for continued operation of the groundwater extraction system.

The above does not diminish the significance of the other constituents. Water quality sampling will be completed for the full suite of parameters at a future time when decisions are being made relative to the possibility of shutting down one or more of the extraction wells. Likewise, the full suite of parameters will be tested for as part of the off-site, OU-3 investigation and recommendations for the suite of analytical parameters for the long term off-site monitoring program will be based upon this future data. Finally, several on-site wells are included in the OU-3 investigation work plan and are identified for sampling and analysis of the full suite of parameters specifically to evaluate the site geochemistry as noted in the comment. However, the objectives for the on-site monitoring program for the groundwater extraction and treatment system are met by the analysis of VOCs and as noted in the previous response, we are no longer in the site characterization phase but rather, performance monitoring. Specifically, the

ROD calls for on-site containment and mass removal to the extent practicable. Documentation that the remedial action is meeting these objectives is obtained through the measurement of water levels (i.e., hydraulic heads) and long term trends in water quality as represented by the VOC concentrations. Documentation of containment through these metrics meets the requirements of the ROD and measurement of the remaining analytical fractions (with respect to the on-site monitoring program for the groundwater extraction system) is not needed until a future date when decisions are made relative to potentially shutting down one or more extraction wells.

In summary, at this time, the collection of analytical data other than VOCs will not have any relevance to the protectiveness or meeting the objectives of the groundwater extraction system as called for in the ROD. In an email dated December 17, 2010, the Agency agreed with this approach with the addition that the full suite of data be analyzed at OW-1, TW-4 and TW-5 during the baseline sampling round. The LTMP will be edited to reflect this agreement and that the need for future analysis of the full suite of parameters at these locations would be dependent upon the results.

TABLE 1
MONITORING WELLS INCLUDED IN THE LONG TERM WATER QUALITY MONITORING PROGRAM

Well ID	Water Bearing Zone	Reference Elevation (ft., msl)	Ground Elevation (ft., msl)	Well Diam.* (inches)	Screen/Open Interval Top (Depth below Ground Surface)	Bottom	Length	Pump Depth Feet Below Ground Surface	Basis for selection of pump depth setting	Est. Volume open interval (gallons)
C-2	Principal	86.24	85.20	4	263	288	25	270	Depth of packer testing conduced during RI	
C-3	Principal	80.52	78.70	4	95	120	25	114	Lower half of screened interval per NJDEP recommendation	16.32
C-4	Principal	80.96	79.10	4	104	129	25	123	Lower half of screened interval per NJDEP recommendation	16.12
C-5	Principal	80.10	78.30	6	99	125	26	118	Lower half of screened interval per NJDEP recommendation	38.63
C-6	Upper Permeable	76.12	73.50	4	77	101	24	80	Caliper logging/fractures in MW-202L	
C-7	Upper Permeable	80.20	78.20	4	145	169	24	158	Fractures/Packer testing at MW-201L	
C-8	Upper Permeable	81.40	79.40	4	116	138	22	133	Lower half of screened interval per NJDEP recommendation	14.36
C-9	Upper Permeable	85.33	83.60	4	91	115	25	109	Lower half of screened interval per NJDEP recommendation	15.99
C-10	Upper Permeable	80.71	78.30	4	102	125	23	119	Lower half of screened interval per NJDEP recommendation	15.01
DMW-1	Principal	85.40	82.90	6	225	250	25	244	Lower half of screened interval per NJDEP recommendation	36.72
DMW-2	Lower Bedrock	85.07	83.60	6	300	325	25	319	Lower half of screened interval per NJDEP recommendation	36.72
DMW-3	Lower Bedrock	80.49	78.70	6	225	250	25	244	Lower half of screened interval per NJDEP recommendation	36.72
DMW-4	Lower Bedrock	80.44	78.60	6	300	325	25	319	Lower half of screened interval per NJDEP recommendation	36.72
DMW-5	Principal	78.89	77.10	6	225	250	25	244	Lower half of screened interval per NJDEP recommendation	36.72
DMW-6	Principal	79.23	77.70	6	300	340	40	330	Lower half of screened interval per NJDEP recommendation	58.75
DMW-8	Lower Bedrock	77.77	76.00	6	300	325	25	319	Lower half of screened interval per NJDEP recommendation	36.72
DMW-9	Principal	76.35	73.80	4	147	171	24	168	Fractures/packer testing at MW-202L	
DMW-10	Principal	79.58	78.00	4	227	251	24	243	Fractures/packer testing at MW-201L	
DMW-11	Principal	85.04	84.00	4	226	250	24	238	Lower half of screened interval per NJDEP recommendation	15.67
MW-102	Lower Bedrock	78.69	77.50	6	325	340	15	333	Midpoint of open interval	
MW-103	Principal	81.09	79.80	6	325	350	25	344	Lower half of screened interval per NJDEP recommendation	36.72
MW-201L	Lower Bedrock	80.56	78.62	2	424	434	10	429	Midpoint of open interval	
MW-202L	Lower Bedrock	76.96	74.89	2	365	375	10	370	Midpoint of open interval	
MW-203UP	Upper Permeable	77.91	76.38	2	122	132	10	127	Midpoint of open interval	
MW-203P	Principal	78.70	76.98	2	257	267	10	262	Midpoint of open interval	
MW-203L	Lower Bedrock	78.90	76.77	2	395	405	10	400	Midpoint of open interval	
MW-204UP	Upper Permeable	75.88	73.92	2	57	67	10	62	Midpoint of open interval	
MW-204P	Principal	75.87	74.42	2	140	150	10	145	Midpoint of open interval	
MW-204L	Lower Bedrock	76.00	73.87	2	327	337	10	332	Midpoint of open interval	
MW-205UP	Upper Permeable	84.40	83.29	2	197	207	10	202	Midpoint of open interval	
MW-205P	Principal	85.12	83.03	2	307	317	10	312	Midpoint of open interval	

TABLE 1
MONITORING WELLS INCLUDED IN THE LONG TERM WATER QUALITY MONITORING PROGRAM

Well ID	Water Bearing Zone	Reference Elevation (ft., msl)	Ground Elevation (ft., msl)	Well Diam.* (inches)	Screen/Open Interval Top (Depth below Ground Surface)	Bottom	Length	Pump Depth Feet Below Ground Surface	Basis for selection of pump depth setting	Est. Volume open interval (gallons)
MW-206P	Principal	74.98	73.50	2	110	120	10	115	Midpoint of open interval	
MW-207UP	Upper Permeable	79.01	77.50	2	102	112	10	107	Midpoint of open interval	
MW-208UP	Upper Permeable	76.93	75.00	2	89	99	10	94	Midpoint of open interval	
TW-1	Upper Bedrock	90.15	89.10	6	13	65	52	60	Five feet above bottom per NJDEP recommendation	76.38
TW-2	Upper Bedrock	85.81	84.30	6	12	60	48	55	Five feet above bottom per NJDEP recommendation	70.50
TW-3	Upper Bedrock	81.59	79.70	6	14	50	36	45	Five feet above bottom per NJDEP recommendation	52.88
TW-4	Upper Bedrock	78.31	76.60	6	19	49	31	44	Five feet above bottom per NJDEP recommendation	44.80
TW-5	Upper Bedrock	76.24	74.30	6	20	45	25	40	Five feet above bottom per NJDEP recommendation	36.72
TW-5A	Upper Bedrock	75.98	74.40	6	20	45	25	40	Five feet above bottom per NJDEP recommendation	36.72
TW-6	Principal	78.88	76.70	6	19	45	26	40	Five feet above bottom per NJDEP recommendation	38.19
TW-7	Principal	80.16	78.00	6	17	50	34	45	Five feet above bottom per NJDEP recommendation	49.21
TW-8	Principal	85.11	83.40	6	16	60	44	55	Five feet above bottom per NJDEP recommendation	64.63
TW-10	Upper Bedrock	79.96	78.50	6	20	60	41	55	Five feet above bottom per NJDEP recommendation	59.49
TW-11	Upper Bedrock	75.76	75.00	6	19	48	30	43	Five feet above bottom per NJDEP recommendation	43.33
Wells for baseline sampling only pending subsequent evaluation.										
OW-1	Overburden	78.37	76.40	4	3	8	5	6	Midpoint of open interval	
OW-2	Overburden	81.64	79.80	4	3	8	5	6	Midpoint of open interval	
OW-4	Overburden	79.96	77.30	4	5	10	5	8	Midpoint of open interval	
OW-12	Overburden	84.65	82.50	4	5	13	8	9	Midpoint of open interval	
									Total volume in open/screened intervals	1020.77
									Average volume in open/screened intervals	39.26

* 2" wells constructed of PVC riser and screen.
  4" wells constructed of stainless steel riser and screen.
  6" wells constructed of black steel riser and open rock interval.

Wells with 10' of screen or less. Pump to be set at midpoint of screen
Well with 15' of screen. Pump to be set at midpoint of screen.
Pump depth to be based on data (caliper/packer testing) obtained from adjacent borehole.

Low-Flow Ground-Water Sampling: An Update on Proper Application and Use

David Kaminski
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QED
Environmental Systems

Today's Webinar Topics

- Early well purging research and guidelines
- Sample bias and error from traditional purging
- What is low-flow purging and sampling?
- Advantages of low-flow purging and sampling
- Low-flow application guidelines
- Other low-flow application issues
  - What do low-flow samples represent?
  - Where should the pump intake be placed?
  - Is there a screen length limit for low-flow sampling?
- Questions and Answers

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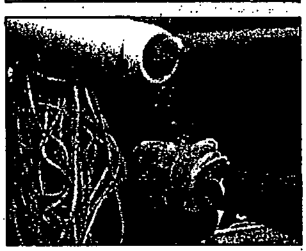
Early purging research resulted in guidelines to remove "stagnant" water from the well



- The "rule of thumb" was 3 to 5 well volumes prior to sampling to get formation water.
- "Low-yield" wells were evacuated and sampled upon recovery, typically within 24 hours.
- Little concern was given to how purging protocols and devices (e.g., bailers) affected the chemistry of ground water samples.

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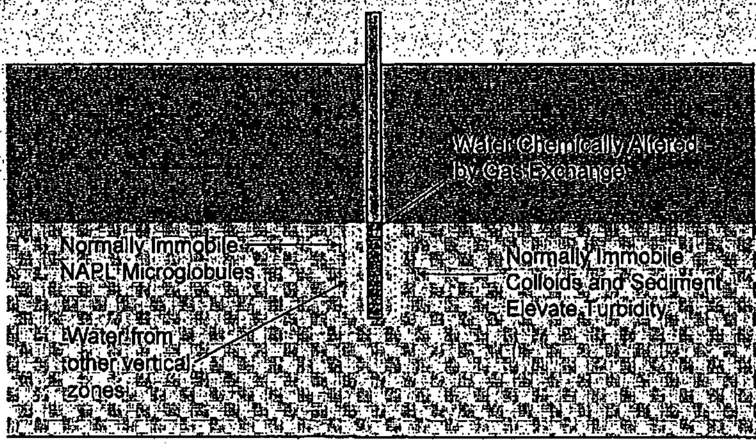
What does the sample represent with traditional purging methods?



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Traditional Well Purging Effects on Sample Chemistry and Quality

- High purge volume can cause underestimation of maximum contaminant concentrations due to dilution.
- High purging rates can cause overestimation due to contaminant mobilization and increased sample turbidity.
- Dewatering lower-yield wells causes losses of VOCs, affects DO and CO_2 levels, and increases sample turbidity.
- Excessive drawdown can cause overestimation or "false positives" from soil gas or from mobilization of soil-bound contaminants in the overlying formation or "smear zone."

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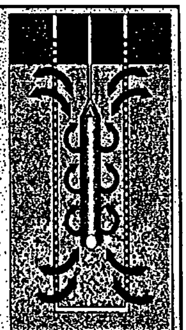
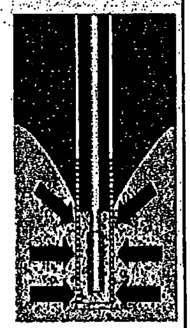
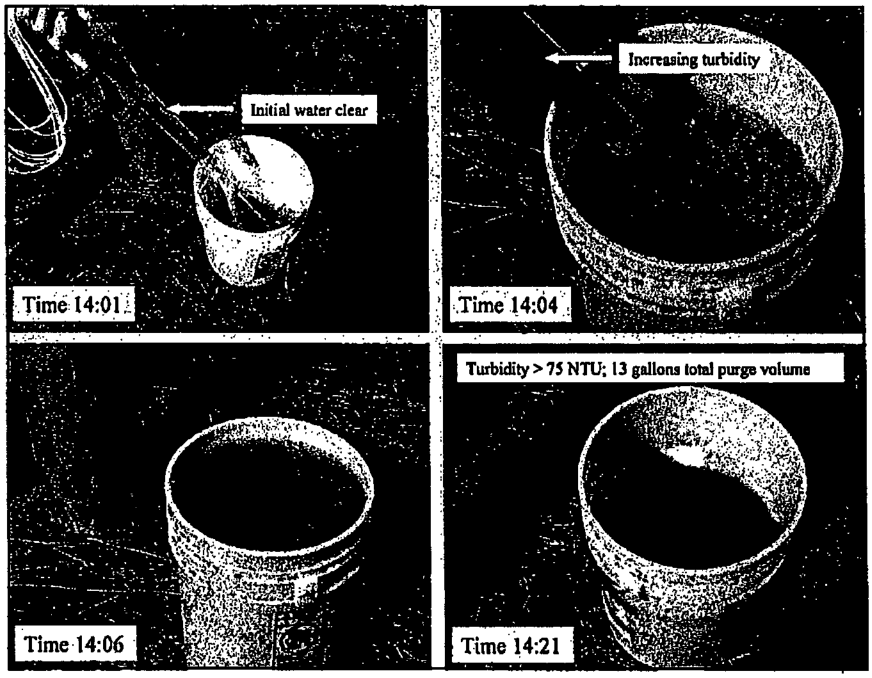
Hand bailing and high-rate pumping can elevate sample turbidity



- Sample filtration adds cost and time in field or laboratory
- Turbidity can elevate metals and some organics (e.g., PAHs) bound to soils
- Filtration affects sample chemistry
  - Turbid samples that are filtered to remove solids are not the same as low turbidity samples
- Gibbons & Sara, 1993 found <u>no statistical difference</u> between filtered and unfiltered samples for metal when turbidity is <10 NTU.
  - Various guidance documents suggest 5-20 NTU is acceptable for sampling (e.g., Florida DEP FS2200, 2006; US EPA Region 1 SOP, 2010)





Limitations in traditional purging methods led to the evolution of low-flow purging

- Low-flow purging and sampling is a methodology that reduces disturbance to the well and aquifer typically caused by bailing or high-rate/high-volume purging.
- Contrary to popular belief, the development of the low-flow purging approach was based on a need to control artifactual turbidity, not to reduce purge water volumes.

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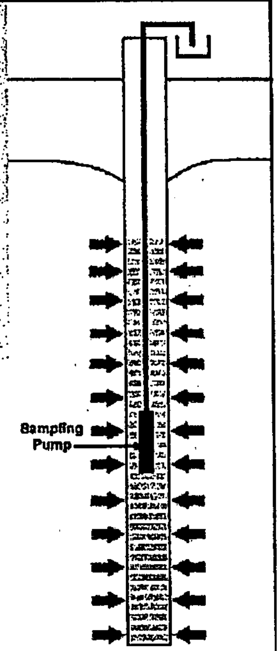
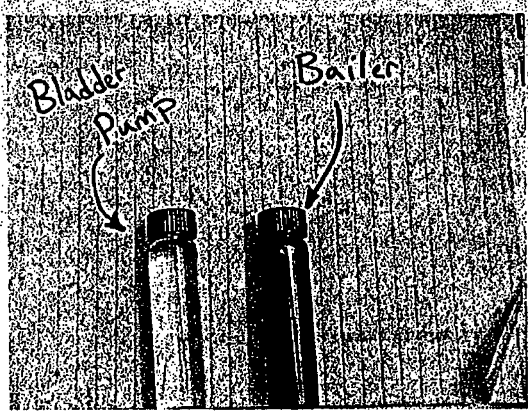
Low-Flow Purging & Sampling

- Low pumping rate minimizes drawdown, mixing and formation stress, isolates stagnant water above well screen.
- Low stress = low turbidity, improved sample accuracy, reduced purge volumes.
- Samples represent naturally mobile contaminants, not stagnant water in the well or mobilized contaminants.
- Purge volume is based on stabilization of indicator parameters measured during purging.



Lower flow improves sample quality



Low-flow purging and sampling controls turbidity and delivers higher quality samples - *a clear advantage*.

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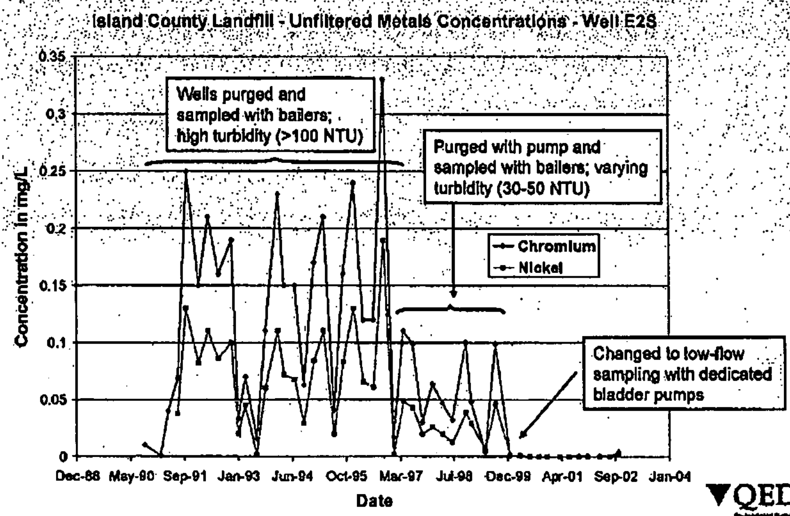
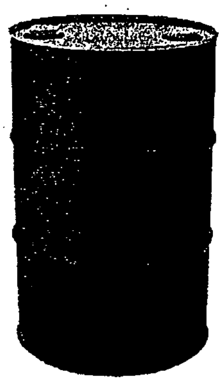
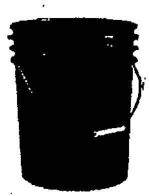
Effect of low-flow sampling on data accuracy and precision



Reduced Purge Water Handling/Disposal



Traditional Well Volume Purging



Low-Flow Purging

Cost Savings with Low-Flow Sampling

(From Schilling, 1995)

	Low-flow Purging	Three Well Volumes
Purging Analysis:		
Total Purge Volume (15 wells)	61 gallons	743 gallons
Average Volume Purged	3.3 gallons	50 gallons
Average Pumping Rate	0.3 GPM	2-5 GPM
Average Purging Time per Well	13 minutes	50 minutes
Total Purging Time (15 wells)	3.25 hours	12.5 hours
Economic Analysis (In US Dollars):		
Time for Purging Wells (a)	$500	$1,875
Disposal costs (b)	$1,300	$3,750
Cost per Sampling Event	$1,800	$5,625
Annual Sampling Costs (quarterly sampling)	$7,200	$22,500
Sampling costs for 30 years	$216,000	$675,000

(a) Two-person crew at $150/hr.USD
(b) First drum = $1,000; additional drums = $300 (drum = 55 US gallons/208 liters).

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Advantages of Low-Flow Sampling

- Low-flow is a consistent, performance based standard for purging, rather than an arbitrary rule of thumb.
- It documents purging process for every sample, overcoming factors that can affect required purge volume.
- Low-flow sampling can reduce sampling costs:
  - Direct cost savings - reduced purge water handling & disposal, reduced purging time (in some wells).
  - Sample Quality - reduced turbidity, more accurate dissolved concentrations, and a better estimate of the true mobile contaminant load
  - Indirect cost savings - improved data accuracy and precision (fewer false statistical "hits"); better data = better decisions.

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Low-Flow Sampling Application Guidelines – The Basics

- Flow rates must be controlled to pump without continuous drawdown (water level must stabilize) and not increase turbidity. Rates of 200 to 1,000 mL/minute are typical.
- Drawdown is based on well performance, not arbitrary guidance.
- Indicator parameters are monitored for stabilization to indicate formation water and purging completeness.
- Dedicated sampling equipment is preferred. Portable pumps require larger purge volumes, can increase turbidity and require decontamination between wells, but are still better than bailing or high-rate pumping.

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Purging Flow Rates

- From US EPA, 1996: "Typically, flow rates on the order of 0.1 - 0.5 L/min are used, however this is dependent on site-specific hydrogeology. Some extremely coarse-textured formations have been successfully sampled in this manner at flow rates to 1 L/min."
- The goal is to achieve a stabilized pumping water level as quickly as possible. This reduces mixing within the borehole, drawing water from the sampling zone.
- Flow rates are established for each well based on drawdown values measured during purging, not an arbitrary value or upper limit.

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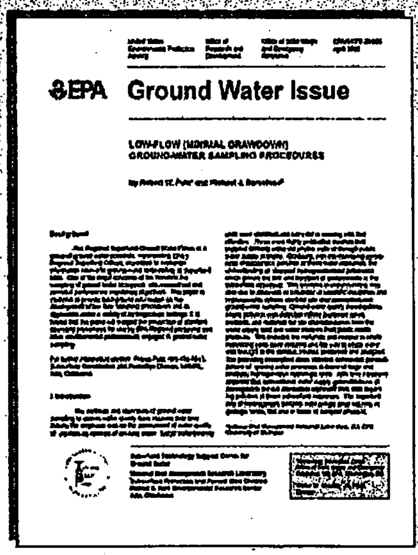
Sampling Flow Rates

- Sampling flow rates "less than 0.5 L/min are appropriate." (US EPA 1996).
- Use rates at or below the purging flow rate for metals and other inorganic parameters, lower rates (100 ml/min.) for VOCs and filtered samples.
- Fill larger sample bottles first, then reduce the flow rate (if needed) for VOCs and any filtered parameters.
- Sampling at 100 ml/minute for all parameters can extend sampling times unnecessarily.

Water Level Drawdown


EPA Ground Water Issue

LOW-FLOW (MINIMAL DRAWDOWN) GROUND-WATER SAMPLING PROCEDURES

From USEPA 1996, Puls and Barcelona:

"The goal is minimal drawdown (0.1m) during purging. This goal may be difficult to achieve under some circumstances... and <u>may require adjustment based on site-specific conditions and personal experience</u>."

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Water Level Drawdown

- The recommendation from Puls and Barcelona (1996) has been interpreted as a maximum drawdown limit in some regulatory guidance documents. There is no data to support this or any other arbitrary drawdown limit.
- A study by Vandenberg and Varljen (2000) shows that the goal is to establish a stable pumping water level during purging, with indicator parameter stabilization following water level stabilization.

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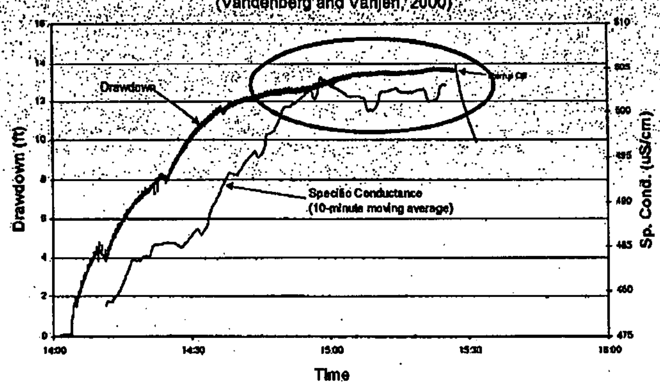
Correlation of Drawdown and Indicator Parameter Stabilization

Drawdown and Specific Conductance During Purging
St. John's Landfill Well D-2A
(Vandenberg and Varljen, 2000)



At the point where the water level stabilized, the indicator parameters (conductivity shown above) and target analytes were also stabilized.

Indicator Parameters for Purging

- Indicator parameters often include pH, temperature, conductivity, DO, ORP (redox) and turbidity.
- DO and C are the most reliable indicators, based on published research and field experience.
  - pH stabilizes readily, often shows little change.
  - Temperature measured at the well head is affected by sunlight, ambient temperature, and some electric pumps
  - Turbidity cannot indicate when purging is completed. It should be measured primarily to support sample data and prevent excessive pumping/formation stress.
- Stabilization criteria are typically $\pm$ 3-10% of readings or a range of units (e.g., $\pm$ 0.2 mg/L DO, $\pm$ 0.2 pH units) where percentages are not appropriate. Stabilization occurs when three consecutive readings fall within the criteria.

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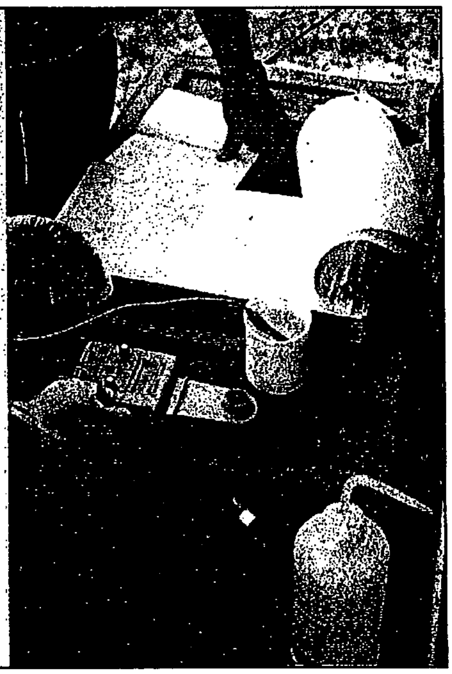
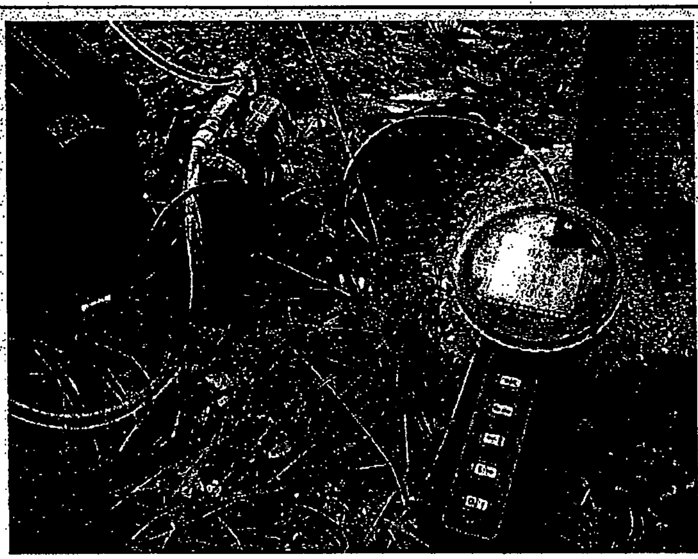
Measuring indicator parameters

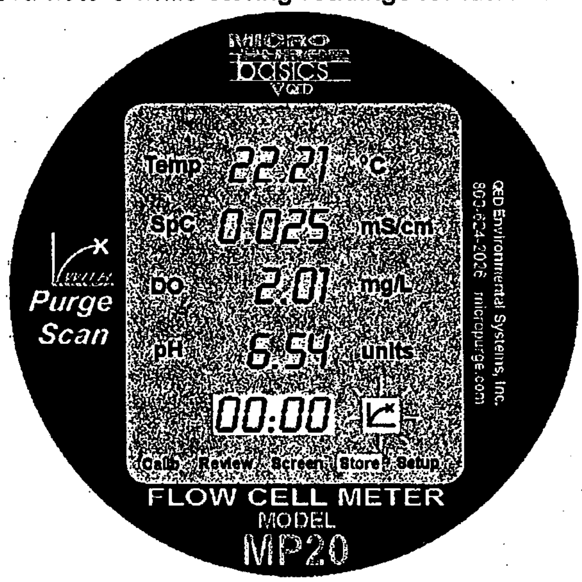
- Traditional approaches use hand-held or bench-top instruments that expose samples to air and make precise measurement intervals difficult.
- Readings may not appear stable even though water chemistry has stabilized.



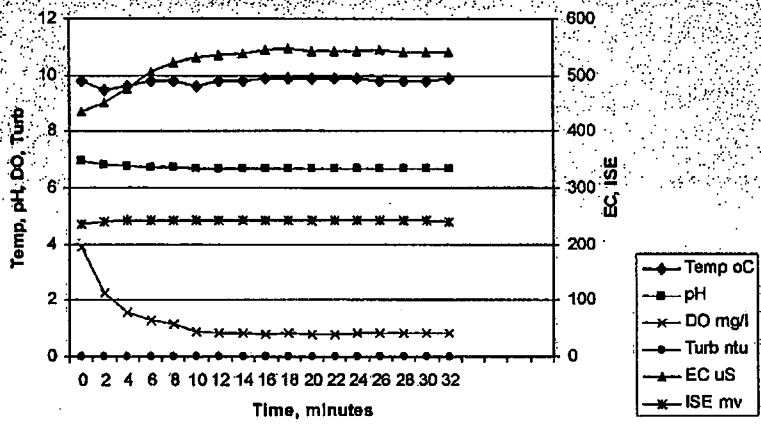


An in-line flow cell isolates water from air, maintaining water chemistry and allowing automated measurement. Open-top "flow containers" can't achieve accurate values for dissolved oxygen or redox due to rapid gas exchange.

Typical flow-cell output provides simultaneous display of parameters while storing readings for future recall



Typical Indicator Parameter Stabilization Curves



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Other issues surrounding proper use of low-flow purging and sampling and regulatory acceptance

- Do low-flow samples represent the entire well screen zone, or just a discrete interval?
- Does the pump inlet location affect sample results?
- Does low-flow sampling work in longer well screens, or is there a practical screen length limit?

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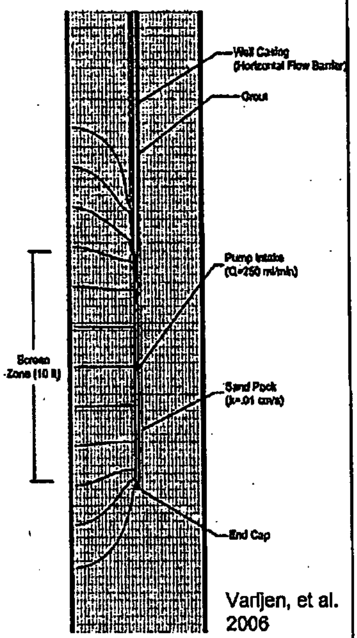
What Does a Low-Flow Sample Represent?

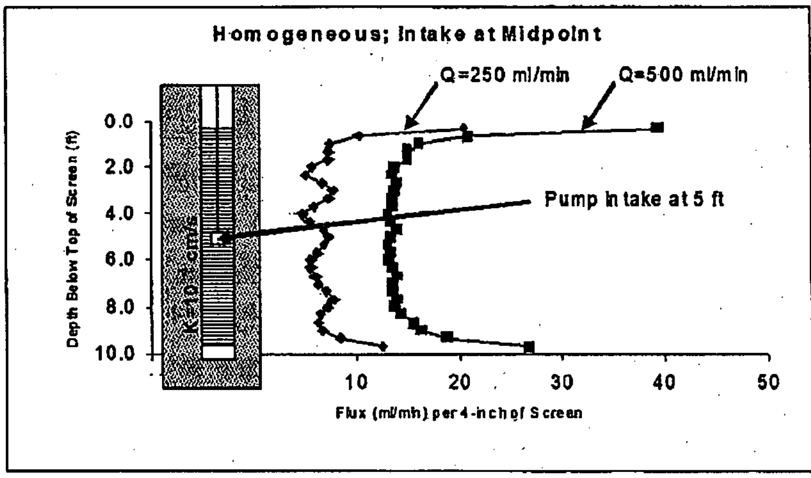
Empirical studies and modeling simulations show that the entire well screen contributes to the sample

- Flow into screen is controlled by the geology near the well, <u>regardless of pump position</u>; high K zones contribute more water
- The actual zone monitored is longer than the length of the screen
- Same for 5, 10, and 20 foot screens
- Applies to both fully submerged screens and screens intersecting the water table



Varljen, et al. 2006

Vertical Distribution of Flux into a 10-foot Well Screen and Effect of Changes in Pumping Rate



Varljen, et al. 2006

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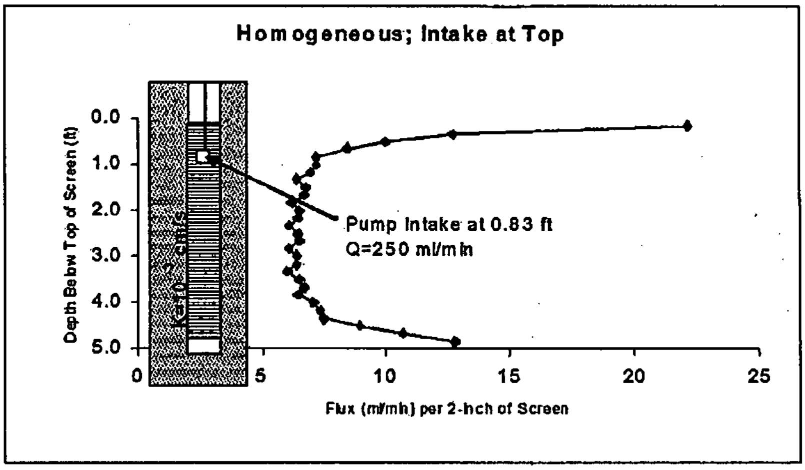
Effect of Pump Placement on Vertical Flux Distribution



Varljen, et al. 2006

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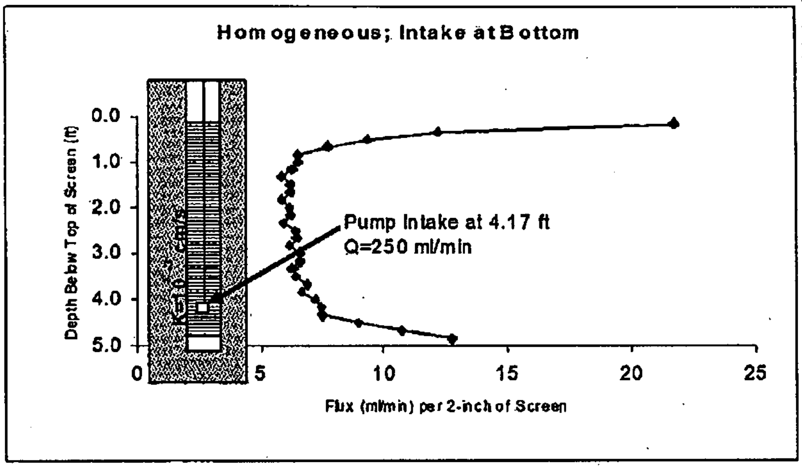
Effect of Pump Placement on Vertical Flux Distribution



Varljen, et al. 2006

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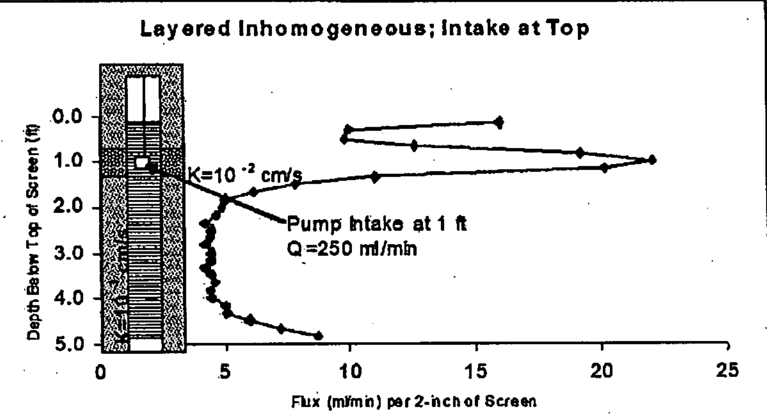
Effect of Heterogeneities on Flux Distribution Pattern



Varljen, et al. 2006

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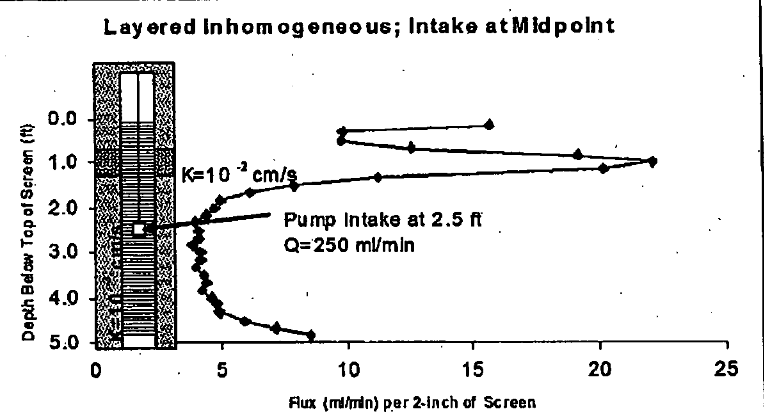
Effect of Heterogeneities on Flux Distribution Pattern



Varljen, et al. 2006

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Vertical Concentration Profiles (Puls and Paul, 1998)

- Low-flow sample concentrations were averaged throughout the well screen; analyte concentrations were known to be measurably stratified within the surrounding formation.
- Low-flow samples were virtually identical to the mean concentration of the multi-level and direct-push samples taken.
- Bailed sample concentrations were biased lower than the low-flow pumped sample results.

Device	DMLS	Geoprobe	Low-Flow	Bailer
Cr (mg/l)	1.69	1.86	1.76	1.05

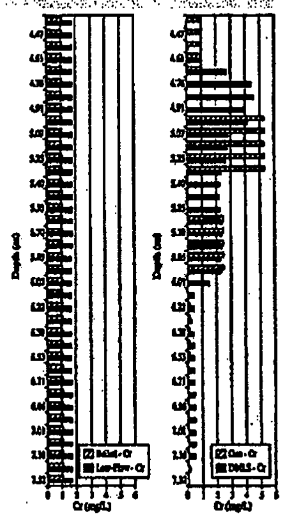
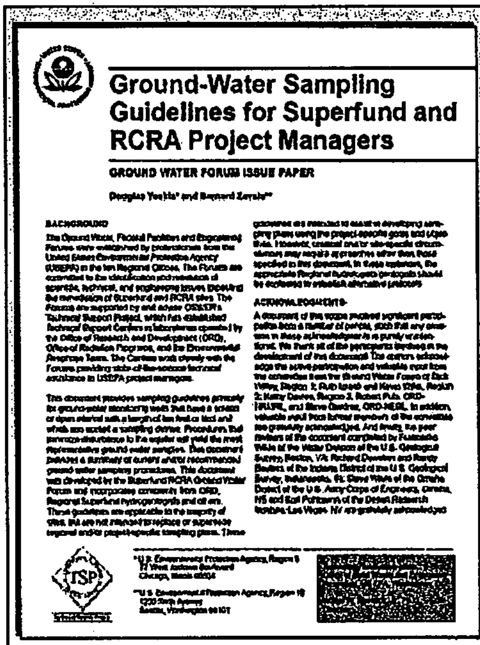


FIG. 8. Chromium Data for Samples Collected Using DMLS, Low-Flo, and Bailed Sampling Approaches for Well 43 in September 1998



Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers

GROUND WATER FORUM ISSUE PAPER

Screen Length Limits Using Low-Flow

- USEPA, 2002 guidelines limit low-flow purging to wells with screens 10' or less.
- Their reference for this limit (USEPA, 1996; Puls and Barcelona) DOES NOT support it.
- No other independent data or any other published study is cited to support the limit.
- Some state regulatory agencies have used the USEPA 2002 guidelines to limit use of low-flow purging to well screens no longer than 5-10 feet.

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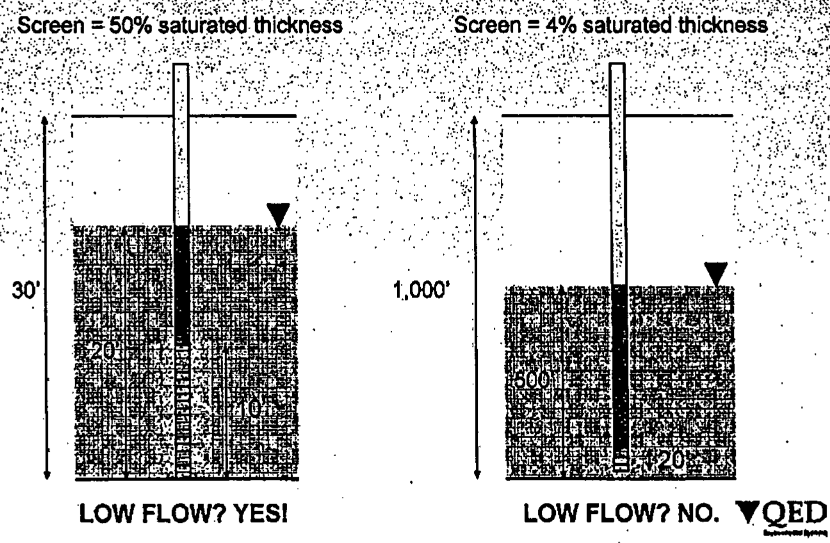
Well screen length controversy



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Screen Length Issues and Objectives

- The issue of well screen length is one of <u>monitoring program objectives</u> and **<u>not</u>** a sampling method issue.
- The length of the screen (i.e., the target monitoring zone) should relate to the saturated thickness and identifiable preferential flow paths and should not be based on an arbitrary design or guideline.
- Previously mentioned studies support using low-flow purging and sampling in well screens to 20 feet.

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Summary

- Traditional well purging methods can cause significant bias and error in groundwater sample data.
- Low-flow purging and sampling can overcome many of the problems associated with traditional well-volume purging, hand bailing and high-rate pumping.
- Proper application of low-flow sampling requires attention to pumping rate, drawdown and indicator parameter stabilization.
- Low-flow purging and sampling will provide a flow-weighted average sample from most monitoring wells when used correctly.
- Pumping rate, drawdown and screen length should not be based on arbitrary limits.

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Questions?

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